that the haptic feedback is not very well integrated into some types of controllers, such as gamepads or other controllers besides traditional joysticks.

## SUMMARY OF THE INVENTION

The present invention provides a haptic feedback control device which includes several improvements to the interface with computer systems and the control of objects. The controller device includes a force feedback pincher mechanism that provides a more natural control over physical or computer-implemented objects. A moveable portion of the housing allows tactile feedback independent of other controls to be output to the user.

More particularly, in one aspect of the present invention, a haptic feedback control device for inputting control signals to a computer and for outputting forces to a user of the control device includes a grip and a pair of moveable pincher members coupled to the grip. Each pincher member is contacted by a finger of the user when the device is operated, where each of the pincher members are moveable in a degree of freedom and the degrees of freedom are approximately within a single plane, such that when one of the pincher members is moved, the other pincher member is also moved approximately the same distance either towards or away from the first pincher member. An actuator is coupled to the pair of pincher members and is operative to output a force on the pincher members in the degree of freedom. A sensor is operative to detect a position of the pincher members in the degree of freedom and output a sensor signal indicative of the position which is received by the computer. Each of the pincher members preferably includes a finger pad for receiving a finger of the user, where the user operates the device by placing a thumb on one of the finger pads and an opposing finger on the other finger pad. The actuator outputs a linear force in a linear direction which is converted to a rotary force that is applied to each of the pincher members.

In a different aspect of the present invention, a haptic feedback control device inputs control signals to a computer and outputs forces to a user of the control device, and includes a housing including a fixed portion and a moveable portion, where the user grips both the fixed and moveable portions when using the device. A coupling, such as a flexure, is coupled between the moveable portion and the fixed portion and allows the moveable portion to move relative to the fixed portion in a direction parallel to a portion of an outer surface of the moveable portion that is contacted by the user. An actuator is coupled to the flexure and outputs a force on the flexure to cause the moveable portion to move with respect to the fixed portion. Preferably, the actuator outputs an oscillating force to cause the moveable portion to vibrate. A preferred embodiment of the device includes a control manipulable by the user and positioned on the moveable portion such that the user feels the force on said moveable portion as tactile feedback when operating the control, and where the control is fixed in position with reference to the moveable portion. For example, the control can be the force feedback pincher mechanism of the present invention or a portion thereof, or can be a button, joystick, or other control.

In one embodiment, the haptic feedback control device of the present invention that includes any of the above aspects is a master device in a telemanipulator system such that the grip is coupled to a linkage of a plurality of members that provides at least three degrees of freedom of motion to the control device, and where the computer controls a slave device in conjunction with motion of the master device. The slave device can include an arm linkage and an opening/closing gripper, where the gripper is controlled by the pincher members. In a different embodiment, the computer displays a graphical environment which with the user interacts using the force feedback control device of the present invention, such as a computer game, graphical user interface, or medical simulation. A local microprocessor can also be included in the control device that receives the sensor signal, reports the sensor signal to the computer, and controls low-level signals to the actuator. Other controls can also be included on the control device, such as a roller that is sensed by a sensor.

In another embodiment, a haptic feedback interface device includes a joystick having two degrees of freedom and a linkage coupled to the joystick for providing the two degrees of freedom. First and second grounded linear voice coil actuators are coupled to the linkage and apply a force to the joystick through the linkage, where a linear motion of a bobbin of the first actuator is approximately parallel to a linear motion of a bobbin of the second actuator. Preferably, the force output by one of the actuators is approximately parallel in direction with respect to a force output by the other actuator, and the forces are approximately orthogonal in direction with respect to a plane formed by two axes of rotation of the joystick.

A method of the present invention for controlling an object with a haptic feedback control device includes outputting a control signal to a computer, the control signal including information describing a manipulation by a user of the haptic feedback control device. The manipulation includes moving a finger pad of the control device in a degree of freedom such that the information in the control signal includes a representation of a position of the finger pad in the degree of freedom. Haptic feedback signals are received from the computer that include information causing a force to be output on the finger pad in the degree of freedom. The force feedback signals also include information causing a vibration of a moveable portion of a housing of the control device surrounding the finger pad. The vibration is preferably caused when the object controlled by the control device interacts with a different object. The object controlled by the user can be a computer-generated object displayed on a display screen or a physical object such as a slave unit in a telemanipulator system.

The improvements of the present invention provide a more natural haptic feedback interface device that is intuitive and easy to operate. The pincher mechanism of the present invention allows a user to easily control objects such as a gripper or virtual hand, and provides haptic feedback based on interactions of the controlled object to allow more detailed and accurate control. The moveable portion of the housing of the present invention provides another channel through which the user can experience haptic feedback independently of any other control mechanisms such as the pincher mechanism, allowing the user to experience feedback concerning interactions of the controlled object to a greater extent, which allows even further natural and accurate control of the object.

These and other advantages of the present invention will become apparent to those skilled in the art upon a reading of the following specification of the invention and a study of the several figures of the drawing.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a first application for the haptic feedback control device of the present invention, in which a master device controls a slave unit in a telemanipulator system;

FIG. **2** is a perspective view of a preferred embodiment of a haptic feedback controller of the present invention for use with the systems of FIG. **1** or FIG. **10**;